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THE VARIATION OF BUTTER-FAT PERCENTAGE WITH AGE IN JERSEY CATTLE.

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BULLETIN 290

THE VARIATION OF BUTTER-FAT PERCENTAGE WITH AGE IN JERSEY CATTLE.*

By John W. Gowen.

SUMMARY

This paper deals with the variation of butter-fat percentage for a pure bred herd of Jersey cattle. The mean butter-fat percentage for this herd is 5.2260±.0073. The comparison of the butter-fat percentage of the milk of 28 different breeds of cattle shows this mean butter-fat percentage as high as that for any breed. The range of variation of these means for the different breeds is between 3.05 to 5.12. The frequency distribution for this range is bimodal one mode occurring at about 3.7 per cent and the other at about 5.0 per cent.

When the variability of the butter-fat percentage is compared with that of the other milk constituents it is found that the variation of the butter-fat percentage from cow to cow is about twice as much as is the variation of the solids-not-fat percentage.

Comparing the variation of the percentages of the different parts of the egg with the variation of the butter-fat percentage it is found that the percentage of yolk and of shell vary to the same degree as the butter-fat percentage but that the percentage of albumin has only half the variation of the butter-fat percentage.

There is a slight negative correlation (—0.1126±.0161) between the age of the cow and the butter-fat percentage which the cow will produce. Described in word this correlation states that for each increment added to the age of a cow there is a

*This paper is an abstract of a longer paper on "Studies in Milk Secretion VI. On the Variations and Correlations of Butter-Fat Percentage with Age in Jersey Cattle," published by the same author in Genetics, May 1920. All literature citations should be made to this complete paper.

slight but consistent decrease in the butter-fat percentage which her milk will contain.

The problems of milk secretion taken from their economic and scientific aspects may be said to be twofold, the first phase of the subject dealing with the problems connected with the production of the quantity of milk, the second phase considering the quality or amount of the constituents per unit volume of the milk. This second phase to the minds of most people has come to mean for milk production the amount of butter-fat per unit volume of the milk or the percentage of this butter-fat.

In studies in milk secretion V of this series of papers the subject of the variations and correlations of milk secretion with age was examined analytically. In this paper it is proposed to deal with the normal fluctuations and associations of the butter-fat percentage for the milk of the same cows used in the preceding study.

The theorem chosen is a small part of that greater problem which has come to be known under the title of developmental mechanics. If a group of like animals are measured for any character and the measurements brought together in a curve representing the individuals in the group, the position of any individual in the curve and the shape of the curve itself are the functions of the two basic variables given such prominence by the work of Galton, environment and heredity. This environment may play a larger or a smaller part in its influence on the character. In most inheritance studies of what might be called qualitative characters, commonly classified as the chemist does in analyzing a chemical compound for its constituent elements as barium present or barium absent, the environmental differences cause little variation in the somatic appearance of the character. In other words put in quantitative terms coefficient of variability of the character is low or as the physicist says the character is constant. The place of the individual in a curve then is due largely if not entirely to heredity.

In the so called quantitative characters the conditions are reversed to a certain extent. The superimposed variability of the conditions under which the organism exists play their part along with heredity in determining the place in the variation curve that the individual will take. Clearly in a study of the hereditary nature of such a quantitative character a knowledge of its variation is essential to any adequate study of the subject. Before the milk production or butter-fat percentage of a heifer and an age cow are compared we must know what has come between for this may be and often is a part of heredity itself.

What these investigations, the first on milk production and the present one on butter-fat percentage, have attempted to do is to analyze the individual variations of the individuals in one curve in terms of their component parts.

Material and Methods.

The material and methods used are the same as those of the previous paper save that certain of the cows kept in the early history of the herd were not tested for butter-fat. The number remaining after these were discarded were 1713 with complete eight months butter-fat percentage records. Throughout this study all of the records are for the first eight months of the lactations that extend at least through the ninth month. For the benefit of those who are unfamiliar with the previous paper, that part of the introduction significant to the data and its manner of collection is quoted.

"The data are exceptional in the following ways: (1) The records extend back to the year 1897 when the herd was organized; (2) the animals are practically all straight island stock; (3) they have been under the oversight and direction of one manager since 1901; (4) exact records are kept of the milk production, butter-fat per cent and butter-fat; (5) many of the individual animals have records for several different lactations.

The elimination of variation caused by varying the five factors above in the records of cows to be used for exact analysis of the laws of milk and butter-fat production is important, as it has been often shown that such differences can influence the herd's production. It is obvious that these records are free from such variables. They constitute a homogeneous group of data representing the island Jersey under constant conditions of management and climate.

The data used for study are all from normal healthy cows. Two diseases have been present in the herd, tuberculosis and abortion. The tubercular animals were all eliminated early in the herd's history by the use of the tubercular test. All records from animals which were proven to be tubercular or which aborted were not used. Records from animals normally healthy but sick during a given lactation were not used. All of the cows have been kept in climatic conditions similar to those of western Virginia.

A word as to the method of keeping the data and its transfer to this Station. All records are made at the time of milking on the dairy milk sheet for the given cow which are kept in the barn. The milking taking place twice a day the records are for night and morning. The weekly production taken from these sheets is transferred to the herd ledger by a trained bookkeeper. The total production for a given month is found together with the yearly production by adding the weekly totals. All records are recorded to pounds and tenths. The cows are tested bi-monthly by the Babcock test and the percentage of butter-fat is recorded beside its corresponding monthly milk yield. All weighings and readings are recorded immediately after they are made so there is little chance of inaccuracy. From these records the author has extracted 1741 complete 8 months records of healthy cows for milk production. Of these 1741, 1713 have records for the butter-fat per cent. The weighted monthly averages of the bi-monthly test have been used to obtain the weighted 8 months average for the 8 months lactation period chosen for study."

VARIATION OF FAT PERCENTAGE IN JERSEY MILK WITH THE AGE WHEN THE TEST WAS MADE.

The records for the mean butter-fat percentage for the 8 months of lactation have been calculated by the author for all cows and for each lactation.

The chief physical constants for these data are presented in Table 1. The four constants presented are the mean, standard deviation, coefficient of variation and skewness.

Several features of general interest concerning butter-fat secretion are evidenced by this table. These points can only be touched hurriedly as it is planned to take up most of them individually in later sections of this paper.

TABLE 1.

Constants of Variation of Butter-Fat Percent for the Successive Ages at Test in Jersey Milk. (8 Months Lactation Period.)

Age at test	Mean	Standard Deviation	Coefficient of Variation	Skewness
2 yrs. 0 mo. to 3 yrs. 0 mo.	5.2635±.0183	0.4662±.0129	8.8581±.3473	+0.1333±.0490
3 yrs. 0 mo. to 4 yrs. 0 mo.	5.2777±.0204	0.4749±.0145	8.9976±.3909	+0.2635±.0556
4 yrs. 0 mo. to 5 yrs. 0 mo.	5.2759±.0196	0.4415±.0139	8.3680±.3744	+0.2744±.0583
5 yrs. 0 mo. to 6 yrs. 0 mo.	5.2345±.0187	0.4132±.0132	7.8938±.3644	--------------
6 yrs. 0 mo. to 7 yrs. 0 mo.	5.1875±.0216	0.4445±.0153	8.5686±.4191	--------------
7 yrs. 0 mo. to 8 yrs. 0 mo.	5.1697±.0223	0.4322±.0158	8.3599±.4359	+0.1047±.0732
8 yrs. 0 mo. to 9 yrs. 0 mo.	5.1553±.0249	0.4156±.0176	8.0619±.4359	—0.1357±.0718
9 yrs. 0 mo. to 10 yrs. 0 mo.	5.1668±.0353	0.4818±.0249	9.3259±.6875	—0.5656±.2963
10 yrs. 0 mo. to above	5.1339±.0288	0.4419±.0204	8.6073±.5647	--------------
Total Population	5.2260±.0073	0.4492±.0052	8.5950±.0995	+0.1003±.0209

The mean butter-fat percentage is the highest in the early ages at which the Jersey cow's mammary gland is functioning. From this high point the percentage of this butter-fat declines irregularly toward the older years of the cow's life. The lowest percentage is reached when the cow is over ten years of age. The difference between the highest mean value of the percentage of butter-fat occurring at three years old and the lowest mean value at ten years and older (5.2777±.0204 and 5.1339±.0288) is 0.1438±.0354 or the difference is 4.05 times the probable error. Such a difference while only mediocre, is likely to be significant. The point will be discussed later in connection with other data. The mean percentage of butter-fat of these Jersey cows (5.2260±.0073) agrees fairly well with that on other Jersey data (5.12) published by the author in table 2 of a previous bulletin. As the data on which the 5.12 percentage was based, included a wide variety of conditions, climate, management, etc. it would appear reasonable to suppose that this figure represents a fair average for the Jersey breed. If such is in fact the case the average production of the Jerseys included in the herd studied are above those of the breed as a whole in butter-fat percentage contained in their milk. The difference is slight in absolute amount, however.

If we examine the butter-fat concentration of the milk of the various breeds summarized in the table referred to above, we see that the Jersey stands at the top of the list of these twenty-eight herds as to the amount of butter-fat produced in its milk. The variation of this average butter-fat is between 3.05 and 5.12 per cent and the Jerseys are more than two per cent greater in mean butter-fat percentage than are the lowest cows of the species. It is especially instructive to study the distribution of these tests a little more closely. For this purpose the tests were grouped into two-tenths per cent intervals. Such a distribution gives some appreciation of the hereditary factors which may be expected to occur in the given breed. The results of such a grouping show that there are two breeds the Jersey and the Guernsey at the top of the scale for the butter-fat concentration of their milk. The percentage is around 5 per cent. In the other group are included the breeds of cattle with a mean butter-fat percentage around 3.7. Between these two groups there is a distinct break between a mean percentage of 4.2 and 4.6. Such a break is highly suggestive of an hereditary difference of at least one unit between these breeds. In this connection the range or spread of the frequency distributions taken for each of these high and low test groups is of interest. Taking the data from the Jerseys of this paper and the Holstein-Friesian of the above mentioned paper the range of butter-fat for the first is 3.65 to 6.95 while that for the Holstein-Friesian is 2.4 to 4.8. As the two frequencies are not very far from normal and as what skewness there is is plus, it follows that the overlap of these curves constitutes only a small area of the total covered by them. The differences of the two breeds are therefore quite distinct. The differences in the scatter of the two groups is also significant as measured by the standard deviation. The standard deviation for the Holstein-Friesian group is $0.318 \pm .004$ and that of this Jersey group is $0.449 \pm .005$ or the difference and the probable error are $0.131 \pm .006$. Absolutely considered the higher fat test cows are more variable than the lower butter-fat percentage cows. In the Jersey or highest group no influence of age on the standard deviation appears to exist.

The coefficient of variation is worth especial study as it gives us in comparable terms the relation between the standard deviation of a distribution and its mean. For our problem the conclusions to be derived from it are not, unfortunately, so straight forward as we are dealing with the index, butter-fat percentage. Reflection on the purpose of the coefficient of variation will make clear that the use of coefficients of variation comes in ridding the coefficient of the terms in which the data are recorded. In other words the coefficient is made a pure number. This is also just what an index does, consequently the use of a coefficient of variation of an index is somewhat like calculating the variation of a pure number. How much this influences the conclusions to be derived from such coefficients of variation is a matter of some doubt. That there is some influence is known; it is, however, altogether probable that this disturbance is not so great but what some conclusion may be drawn from the calculated coefficients of variation even admitting these disturbances.

The need for such a comparison become especially clear in our data on butter-fat percentage. Here the character studied is the concentration of the butter-fat in the milk and not the total mass or pounds of this fat secreted for a lactation. Information is desired on the variation of the functioning of the cells which secrete this concentrated fat emulsion in comparison with those of cells of the mammary secreting a low concentration of fat. Furthermore comparison data for the variation of the ability of other glandular cells in their secretory activity is desirable. For these reasons it has seemed best to present coefficients of variation for such data realizing in so doing that too wide conclusions cannot be drawn from them. The data for this comparison are given in Table 2. In this table are also included, to save the table space, the calculated skewness of the frequency distributions as these data will be used shortly.

The standard deviations of the butter-fat percentage of the milk produced by the four breeds, Jersey, Guernsey, Holstein-Friesian and Ayrshire shows a relation to the mean concentration of this butter-fat, such that, the breeds producing the greatest concentration have a significantly larger variation than do the breeds whose milk contains less fat. The solids other than the butter-fat, contained in the milk of the Holstein-Friesian cows, show approximately the same standard deviation as does the butter-fat of this breed. Such mean solids-not-fat percentage of about two and one-half times the mean butter-fat percentage leads to a coefficient of variation of about half the size of that for the butter-fat percentage.

TABLE 2.

The Variation and Amount of Asymmetry of the Concentration of the Components of Known Secretions.

Character	Mean Percentage	Standard Deviation	Coefficient of Variation	Skewness	Source of Data
Milk					
Jersey butter-fat Percentage	5.22±.01	0.45±.01	8.60±.10	+0.10±.02	*This paper*
Holstein-Friesian butter-fat Percentage	3.44±.01	0.32±.00	9.23±.12	+0.15±.02	Gowen
Holstein-Friesian Solid-not-Fat Percentage	8.60±.01	0.34±.01	3.92±.11	+0.17±.05	Gowen
Ayrshire Butter-Fat Percentage	3.68±.01	0.32±.01	8.76±.17*	+0.16±.03	Vigor
Guernsey Butter-Fat Percentage	5.03±.00	0.48±.00	9.45±.01	+0.12±.01	Gowen
Egg of Domestic Fowl†					
Albumen Percentage	59.83±.04	2.75±.03	4.59±.03*	+0.27±.02*	Curtis
Yolk Percentage	30.00±.04	2.70±.02	8.99±.06*	+0.21±.02*	Curtis
Shell Percentage	10.13±.01	1.04±.01	10.30±.06*	+0.10±.02*	Curtis

*These constants were calculated by the author from the data presented by the different investigators whose papers are cited. The means and standard deviations cited from these authors have been checked by the author.

†The author is indebted to Dr. M. R. Curtis for the loan of the original data on which the calculations were based for the variation of the parts of the egg.

The standard deviations of the percentage constituents of the egg parts are all higher than those for the percentage constituents of the parts of the milk. Thus the standard deviations of the percentage of albumen in the egg is 2.75, that of the yolk is 2.70 and of the shell 1.04; whereas for the butter-fat percentage the standard deviations range from 0.32 to 0.48. This would seem to indicate a real difference in variability between the functioning of the gland cells of the udder of the cow and the oviduct of the hen. The mean percentage of the different parts of the egg are considerably larger than those of the milk parts, however. For the percentage of yolk and the percentage of shell the coefficients of variation agree well with those found for the variation of the butter-fat percentage. The coefficient of variation for the albumen does not agree with that of the butter-fat percentage but does agree with that of the solids-not-fat in the milk of the cow. In the formation of the egg of the domestic fowl it is well known that only certain cells can secrete a given substance. The similar variation of the protein containing solids-not-fat and the albumen portion of the egg and the similar variation of the lipin portion of the milk the lipin portion of the egg calls attention to the lack of knowledge concerning the exact nature of this secretory activity of the mammary gland and the possibility that there may be two types of cells in this gland of separate and distinct function.

Returning to Table 1, no skewness is present in three of the nine distributions. In the remaining six distributions at the different ages there are four in which the skewness is plus and two in which the skewness is minus. The frequency distributions of butter-fat percentage at the first three years of the lactation life of the Jersey cow are skew in the plus direction. This skewness increases to the fifth year of lactation. At this age the curves for the butter-fat percentages are symmetrical. The minus skewness of the eight and nine years of age are quite unlooked for. Negative skewness is on the whole, rare. Why milk production at these ages should change to become minus and minus to as large an amount in the ninth year of age is not clear.

The general frequency distribution for the butter-fat percentage of Jersey milk has a plus skewness of rather small amount. The comparison of the skewness for this Jersey data with that of other breeds is given in Table 2. These data show that butter-fat percentage of the four breeds, Jersey, Holstein-Friesian, Ayrshire and Guernsey is plus and of small amount. The distribution of each breed have approximately the same numerical value for this constant.

Comparison of the skewness of the other milk solids with those of the butter-fat percentage distributions show these distributions are, within the limits of random sampling equal in their asymmetry.

The comparison of the skewness of the percentage composition of the parts of the egg reveals the fact that the skewness of the percentage of shell is of about equal amount with those of the different parts of the milk. The skewness of the percentages of yolk and of albumen are slightly greater than those of any of the butter-fat percentages contained in the milk of the different breeds. In comparison with their probable errors the difference between these values is in certain cases undoubtedly significant in other cases the significance of the data is not so clear.

The conclusion appears justified that the frequency distributions for butter-fat percentage in cow's milk are slightly asymmetrical and that this skewness is in the plus direction.

THE CORRELATION OF JERSEY 8 MONTHS BUTTER-FAT PER CENT WITH AGE OF THE COW AT COMMENCEMENT OF TEST.

Increase in age of the cow from the time she is a heifer to the time she is at her maximum productivity at 7 years has been shown to bring about a logarithmic increase in the quantity of eight months milk produced by that cow. The effect of increasing the age of the cow on the quality is of equal interest to the student of the physiological behavior of the mammary gland. The data for this comparison in the herd of pure bred Jersey cows with which this study deals are shown in Table 3.

TABLE 3.

Correlation Surface for Butter-Fat Percentage and Age at Test For Jersey Cattle. (Lactation Period 8 Months).

	BUTTER-FAT %																								
Age at Test	3.50—3.65	3.65	3.80	3.95	4.10	4.25	4.40	4.55	4.70	4.85	5.00	5.15	5.30	5.45	5.60	5.75	5.90	6.05	6.20	6.35	6.50	6.65	6.80	6.95—7.10	Total
1:6— 2:0							1	3	2	3	3	3	7	7	3	4	1	1							38
2:0		1				4	11	12	13	24	35	37	42	25	10	13	10	5	5	2			1		250
2:6						1	3	1	3	5	7	7	6	3	2		3	3			1	1			46
3:0						3	6	5	12	11	18	34	15	19	16	6	8	1	1	1		1	1		158
3:6						1	3	9	4	13	13	10	7	6	7	3	3	1	2	2	2	1			87
4:0						1	2	5	12	18	15	15	18	13	13	9	4	3	2	1			1		132
4:6						1	2	6	9	14	12	15	11	8	8	3	6		1		2				98
5:0					1			7	11	9	18	13	14	14	10	6	3					1			107
5:6					2		4	9	5	15	13	21	14	13	7	4	5	1		1	1				115
6:0						4	3	6	6	12	10	13	9	13	2	5	3	1	1	1	1				90
6:6				1	1	2	3	6	9	11	18	13	14	8	8	3	2	3							102
7:0					1		4	3	11	10	6	12	16	5	5	2	3	2					1		81
7:6				2		2	3	6	6	12	13	16	12	11	1		3	3							90
8:0			1			1	5	4	7	3	11	10	10	10	3	1	4								70
8:6						2	3	6	1	7	6	11	8	8	1	2	1	1							57
9:0			1	1		2	1	3	1	6	3	4	11	5	2	6	2								48
9:6					1	3	1	3	4	3	4	3	3	8	2	1	1								37
10:0					1		1	1	4	4	2	4	3	6	1	1			1						29
10:6						1	1	3	1	3	1	3	4	2		1	1								21
11:0						1				1	3	4	5	1	1	1		1							18
11:6						1			1	2		6		1	1										12
12:0				2					1	1	1	1			1			1							8
12:6						1		1	2		2		1	1											8
13:0					1	1			1		1	2													6
13:6													1	1											2
14:0											1	1													2
14:6														1											1
15:0																									
15:6—16:0																									
Total		1	2	6	8	32	57	99	126	187	216	258	231	189	104	71	63	27	13	8	7	4	4		1713

The correlation and its accompanying constants for these two variables is shown in Table 4.

TABLE 4.

Constants Measuring the Intensity of the Association Between Age and Butter-Fat Percentage Found in the Eight Months Milk of Jersey Cows.

r	η	$\eta^2 - r^2$
—0.1126±.0161	0.1478±.0159	0.0092±.0031

From these constants it is clear that there is a slight significant relation between the age of the cow and the concentration of the butter-fat contained in her milk. The value of η corresponds well with that of r except that it is different in signs as η by its derivation is a positive quantity. The regression is clearly a linear one as the values of the constants to measure the linearity ($\eta^2—r^2$) are less than three times their probable error (0.0092±.0031).

In comparison with the previous curves on the milk production for the same cows plotted on the same age basis the curve for the butter-fat percentage shows that while the milk production rises logarithmatically to a maximum and then falls off more slowly, the butter-fat percentage actually is slightly decreasing in this milk, as the age increases. This means that while the mass of butter-fat produced by a cow follows in general the same kind of function as does the milk, there is this difference; vs. the butter-fat relative to the milk is always decreasing slightly in amount.

This fact of a slight negative correlation and a consequent decline in the mean butter-fat percentage produced with the advancing age of the Jersey cow is interesting in comparison with the known facts for other breeds. As previously shown by the writer the correlation between age and butter-fat percentage for the year test Holstein-Friesian cows is —0.0546±.0181. Vigor has shown the correlation between these same variables to be —0.2744±.0255 for Ayrshire cattle (the author has checked the results and found it correct). From unpublished data of the writer the correlation of advanced registry Guernsey cattle for these same variables is —0.1174±.0134. The correlation for the Jersey is equal to —0.1126±.0161. Two of these correlations are based on advanced registry data and may be considered as subject to a selective influence on the data. The distributions do not look as if such a disturbing factor had been present as there is no evidence of truncation and as shown in a previous part of the paper the frequency constants agree quite well with those of the Jerseys and Ayrshires known to be untruncated. It seems therefore that the constants above should be directly comparable as to the relation of age and buter-fat percentage of these breeds.

The Jersey correlation coefficients do agree very closely with those of the Guernseys. The Ayrshire do not agree at all with any of the other breeds for difference of the correlations of Ayrshire and Jersey is 0.1618±.0301 or 5.4 times its probable error. The multiple times the probable error is greater for the Holstein-Friesians. The difference of the Holstein-Friesian correlation from that of the Jerseys is probably not significant as it is only 2.4 times the probable error. The correlation for the Holstein-Friesian age and percentage of butter-fat produced is probably not significant.

The Ayrshire results are obtained under the conditions of Scotland whereas, the other results, are on cattle kept in this country. This may possibly account for the difference in influence of age on butter-fat concentration of Ayrshire cows as compared with these other breeds or it may equally well mean that the Ayrshires are innately different from the other breeds.

The correlation for the Holstein-Friesian in comparison with the correlation for the other breeds is small. It does show the same sign as the other correlations.

These considerations taken together lead to the following conclusion which may be expressed tentatively as follows: each increment of time added to a cow's life causes a slight decline in the concentration of butter-fat that the cow's mammary gland can secrete into the milk.

In the bulletin following this, the relation of the butter-fat percentage of one lactation to the butter-fat percentage of a subsequent lactation will be analyzed using the records from this same herd.

The Mathematical Handling of Breeding Data.

All investigations and inquiries that involve numbers require more or less mathematical handling. Where the data involved are few an arithmetical mean or average is all that is required. For instance in the chemical analysis of a fertilizer rarely more than two or at the outside three determinations are involved. Hence adding these together and dividing by the number of determinations gives the average. On the other hand in plant and animal breeding work where hundreds or even thousands of units of data are involved the handling involves not merely arithmetical but logarithmic methods also and other problems arise than can only be solved by the calculus.

These data that have to be handled in this complicated way and the results that can only be stated mathematically furnish the only sources for the answer to the questions that confront the practical animal and plant breeder. They must be stated in a mathematical form in order to present the results as they exist. The attempt to put them into everyday language impairs their accuracy of definition. The terms used are new and unusual. For the biometrical methods of handling these data are new. In time these will come to be as readily understood as are the terms used in feeding stuffs and fertilizer analyses.

In its publications of the results of biological investigations the Maine Agricultural Experiment Station is embarrassed by just how far the steps in handling the data upon which the conclusions rest should be printed in the papers designed primarily for the men who are at the fore in the practical agriculture of the State. The bulletins of the Maine Agricultural Experiment Station give in black type at the beginning the conclusions arrived at in the publication. The text gives some of the more obvious and more readily comprehended steps in the investigation. The papers sent to the scientific journals go into mathematical handling in much more detail.

With the hope of making the matter of the bulletin clear a sort of dictionary of the terms employed has been prepared and will gladly be sent on request to the undersigned.

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